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June 1992

EXTENDED-INTERACTION KLYSTRON FOR THE AN/TPS-43-E RADAR SYSTEM

Varian Associates Inc.

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Rome Laboratory
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13. ABSTRACT (Maximum 200 words)
This effort was directed at developing and demonstrating a form, fit and functional extended-interaction klystron replacement for the VA-145E Twystron in the AN/TPS-43E radar system. A suitable extended-interaction output circuit had already been demonstrated under Contract F30602-78-C-0029.

A total of three tubes were built and tested under this program. All performed to full specifications when tested under normal factory test conditions. However, none of the three tubes performed satisfactorily in a simulated AN/TPS-43-E system (a Westinghouse TPS-3 system). Unstable tube operation was caused by the rotary joint, which has a severe mismatch near the operating frequency band. After this condition was discovered with tube S/N 001, tubes S/N 002 and S/N 003 were built in an attempt to overcome this near-short-circuit condition by reducing the output resonator impedence near the problem frequencies. This solution was only partially successful. These later tubes operated satisfactorily at some orientations of the rotary joint but would become unstable at the worst mismatch points. The task of designing a special tube that would include novel features for overcoming the severe system mismatch problem was determined to be outside the scope of this contract and this effort was concluded.

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1.0 INTRODUCTION

1.1 SCOPE

This is the final technical report for Rome Air Development Center (RADC) Contract Number F30602-83-0161. The objective of this program was to develop a cost-effective replacement for the VA-145E Twystron®, which is the microwave tube final amplifier in the AN/TPS-43-E tactical radar. This work was proposed as a result of earlier development programs on extended-interaction klystron (EIK) technology sponsored by Rome Air Development Center under Contracts F30602-78-C-0029 and F30602-80-C-0089.

The extended-interaction klystron replacement for the VA-145E Twystron was assigned the tube-type number VKS-8345 and is so referenced in this report.

1.2 BACKGROUND

The microwave final amplifier in the AN/TPS-43-E radar transmitter, the VA-145E Twystron, adequately meets the system requirements for high peak power and wide instantaneous bandwidth. Although a proven and dependable tube, the VA-145E has always been a challenge to manufacture and repair because of its complexity. The VA-145E is a hybrid klystron/traveling-wave tube, with four conventional klystron buncher cavities followed by a traveling-wave output circuit (see Figure 1a). The traveling-wave output circuit contains 14 slot-coupled cloverleaf cavities and an output coupler. As is true for all traveling-wave tube circuits, the periodic cloverleaf cavity slow-wave structure can propagate more than one rf mode. To maintain operation in the proper mode and avoid interference from unwanted modes, the circuit must be carefully loaded with rf-lossy material. The input stage of the traveling-wave structure is terminated with a delicate sever load to absorb unwanted backward waves. Each cloverleaf cavity is loaded with rf-lossy material (Kanthal) to limit the gain and prevent unstable behavior. Also, each cloverleaf cavity contains several loading loops coated with Kanthal to suppress the "rabbit ears" instability that occurs at the π-point of the fundamental mode during the rise and fall time of the beam voltage pulse.

When the Kanthal is applied correctly and each cloverleaf cavity and loading loop is properly tuned, the VA-145E Twystron performs well. However, controlling these critical processes during the manufacturing and repair cycles is, at best, complicated. If too little loss is applied to the circuit, the tube will demonstrate high gain and instability; too much loss will

result in low gain and low rf power output. In either case, the tube must be reworked and the entire output section replaced. The manufacturing yield for this tube has traditionally been less than is acceptable under present-day standards.

In contrast to the traveling-wave tube output circuit used in the VA-145E, the extended-interaction output circuit consists of two simple adjacent klystron cavities coupled by a slot in their common wall (see Figure 1b). Because the extended-interaction structure is a standing-wave circuit, no delicate sever load or lossy cavity loading is required to suppress unwanted propagating modes. Furthermore, if the dimensions of the two cavities and the coupling slot are correctly chosen to avoid higher-order resonant modes in the lower harmonic bands, no rf loss of any kind is required in the extended-interaction output circuit. Given equal rf performance, the simplicity of the extended-interaction circuit over the traveling-wave-tube circuit is appealing. Table 1 provides a detailed mechanical comparison that further emphasizes the advantages.

TABLE 1
Mechanical Comparison of Output Circuits for the Twystron and Extended-Interaction Klystron

Feature	VA-145E Twystron Output Circuit	EIK Output Circuit
Number of Cavities	14	3
Lossy Sever	Yes	No
Kanthal Coatings	Yes	No
Complex Transducer	Yes	No
Mode-Loading Loops	Yes	No
Number of Circuit Elements Requiring Cold Test	20	5
Number of Major Piece Parts	25	9
Linear Inches of Weld	11	0
Linear Inches of Braze	252	36

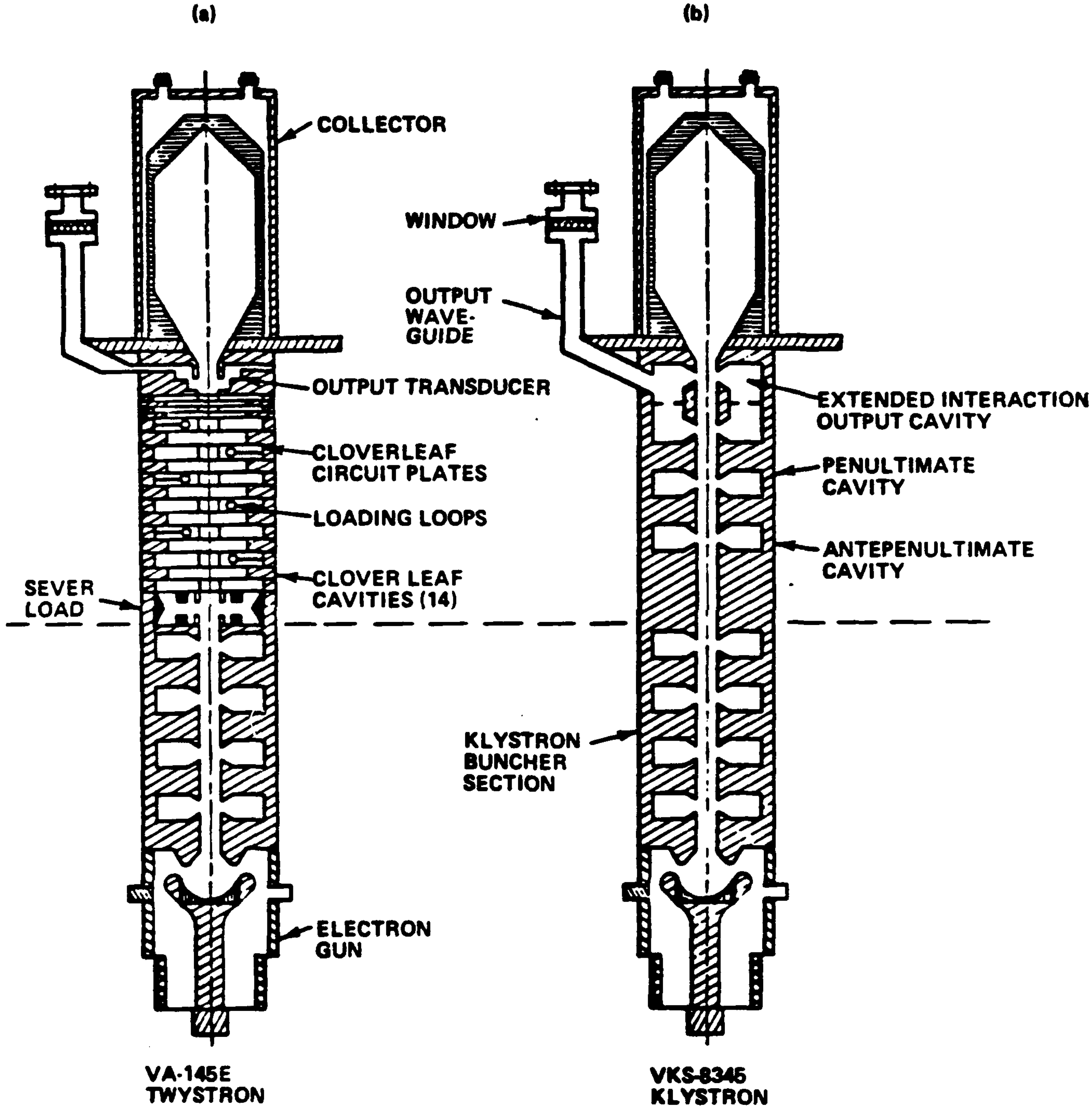

FIGURE 1.
Schematic Layout of the VA-145E Twystron and VKS-8345 Klystron

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The extended-interaction klystron also had the potential to significantly improve reliability in field operation. Failed VA-145E's returned from the field exhibit a high incidence of electron-beam damage on the relatively delicate cloverleaf cavity plates. The cause of this damage is either magnetic focusing anomalies or unprotected waveguide arcing. Either of these conditions can cause the electron beam to diverge and strike the cloverleaf cavity plates. In the extended-interaction output circuit as shown in Figure 1b, the drift tube and cavity sections are inherently more rugged and hence more tolerant of any adverse operating condition encountered in the field. The advantages of the extended-interaction klystron over the VA-145E Twystron were quantified in a life-cycle cost comparison analysis.[1] Included in this study were the manufacturing costs, repair costs, and expected improvements in tube life. The results of this study clearly favor the extended-interaction klystron. With this background information, development of the VKS-8345 extended-interaction klystron began.

2.0 EXTENDED-INTERACTION OUTPUT CIRCUIT KLYSTRON TECHNICAL APPROACH

The simplest form of an extended-interaction output circuit is two adjacent klystron cavities coupled by a slot in their common wall. When used as an output circuit, only one of the cavities (usually the second) is directly coupled to the external load. This type of circuit (shown in Figure 2) has three fundamental natural resonant modes: the π mode, the 2π mode, and the slot mode. In the π mode, the gap rf voltages are approximately 180 degrees out of phase; in the 2π mode, the gap rf voltages are in phase. The slot mode occurs at a frequency generally determined by the dimension of the coupling slot between the cavities.

The extended-interaction output circuit can be designed to operate in either the π mode or the 2π mode. Each of these modes, when well separated in frequency, acts as a single-tuned resonator. However, because of the higher intrinsic impedance of the two-cavity resonator, either mode will have nearly twice the bandwidth potential of a single cavity. The bandwidth can be further improved for either mode by the addition of a filter cavity in the output coupler to form a filter-loaded resonator. In this approach, the π mode and 2π mode remain well separated in frequency, and the circuit is operated only near the frequency of the chosen mode.

Although the two-cavity, single-mode approach described in the proceeding paragraph offers significant bandwidth improvement over a single-cavity output system, a different approach can provide even more bandwidth. Instead of choosing to operate in one or the other of the two fundamental modes, it is possible to dimension the coupling slot between cavities so both the π-mode and the 2π-mode frequencies are closely spaced and lie near or within the desired operating band. In this case, both modes contribute to the interaction impedance, yielding a double-peaked impedance response. An extended-interaction output circuit designed in this manner is called an overlapping-mode circuit. This approach, which has even more bandwidth than the filter-cavity loaded-π-mode or 2π-mode circuits, was the configuration chosen for the VKS-8345 extended-interaction klystron.

Unlike a traveling-wave output circuit, the stability of the three fundamental modes (π mode, 2π mode, and the slot mode) is analytically predictable. When the cavity and slot dimensions are properly chosen, the three modes will be stable at all beam voltages and currents to well above the operating levels. This fact was amply demonstrated on earlier extended-interaction klystron programs. [2]

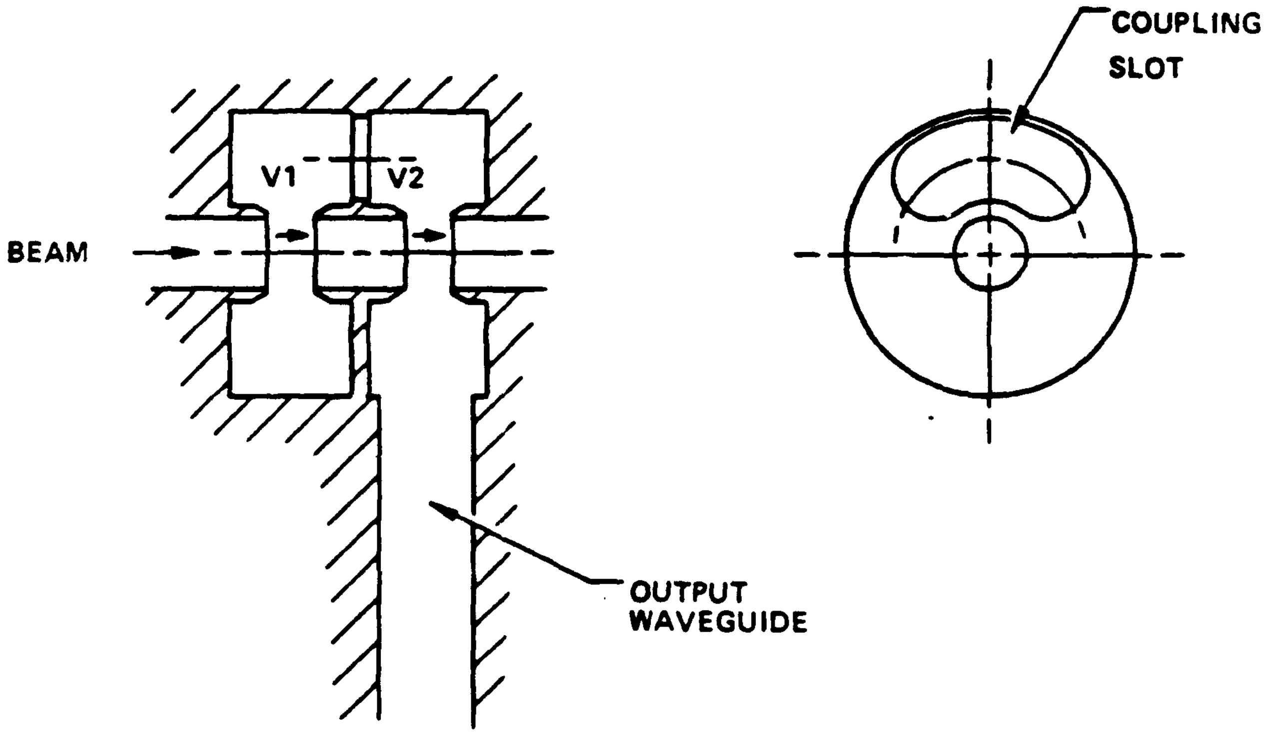

FIGURE 2.
Two-Gap, Slot-Coupled, Extended-Interaction Resonator

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Stable operation of the fundamental modes is a straightforward achievement. However, complete stability requires the circuit to be free of higher-order modes in all the lower harmonic bands of the fundamental operating range. This condition is not always easily achieved. Cavity and slot dimensions optimized for the fundamental frequency range may produce in-band harmonic resonances. Thus, the design of the output circuit becomes an iterative process wherein the optimum circuit dimensions for fundamental operation may have to be compromised to achieve mode-free harmonic bands. As we will discuss later, such was the case in this program.

2.1 EXTENDED-INTERACTION OUTPUT CIRCUIT FOR THE VKS-8345

Because of the previous work on extended-interaction circuits under Rome Air Development Center Contract Number F30602-78-C-0029, the development of a new output circuit for the VA-145E with ample impedance-bandwidth product was a low-risk effort. Under the earlier contract, a two-cavity extended-interaction output circuit was developed and installed on a standard VA-145E in place of the traveling-wave-tube output circuit. Two additional fixed-tuned buncher cavities were also installed as shown in Figure 1. The full bandwidth of the output circuit was evaluated by tuning the buncher cavities to achieve saturated gain at each frequency. At a beam voltage of 110 kV, a 1-dB bandwidth of 12% was achieved with a minimum power output of 2.5 megawatts (see Figure 3). These results demonstrated that a two-cavity extended-interaction output circuit could easily provide the bandwidth, power output, and efficiency required by the AN/TPS-43-E radar system.

The actual design of the extended-interaction output circuit for the VKS-8345, Serial Number 001, was produced following the procedures documented in the earlier programs.[2,3] Because the extended-interaction output circuit has more than enough bandwidth for this application, the major task of this program was to achieve sufficient gain-bandwidth performance from the input buncher section.

2.2 OVERALL DESIGN OF THE VKS-8345

2.2.1 Gain-Bandwidth Considerations

To be a form, fit, and functional replacement for the VA-145E, the VKS-8345 must operate in the existing VA-145E focusing solenoid. This means the tube's input-to-output

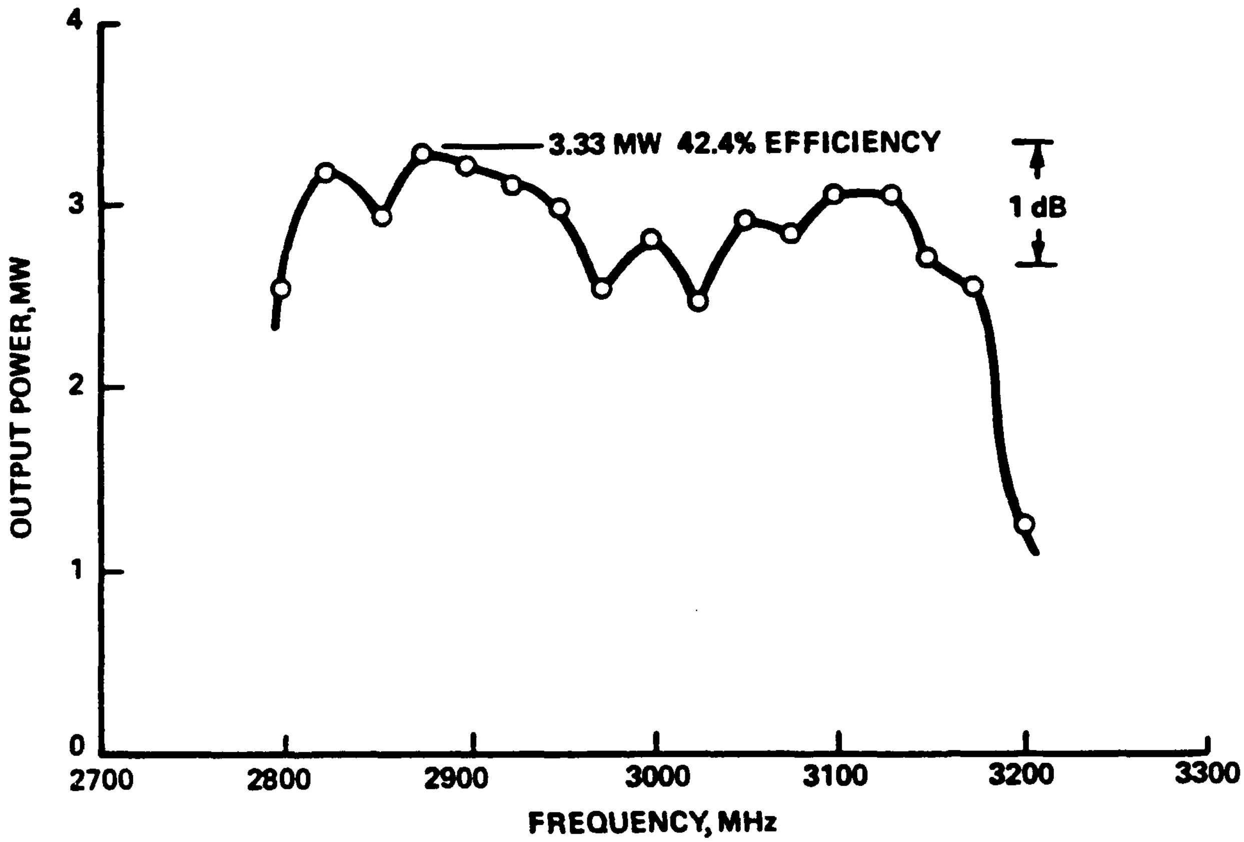

FIGURE 3.
Power Output versus Frequency From an Experimental Extended-Interaction Klystron

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pole-piece dimension is fixed. Within this length the VA-145E provides ample gain because the traveling-wave-tube circuit, in addition to coupling power off the beam, provides useful gain.

Such is not the case in the extended-interaction output circuit. All of the gain must be provided by the input buncher section. The two additional buncher cavities just prior to the output circuit are both tuned relatively high in frequency (out of band) to enhance efficiency; hence, they add little gain. Stated another way, a Twystron has greater gain per unit length than does a klystron, all other things being equal.

Several options were available to produce adequate gain-bandwidth in the buncher section of the VKS-8345. Our choice was to reduce the drift-tunnel and beam diameters slightly. These changes increase the beam-to-cavity coupling and add electrical length to the tube. Increasing the beam-to-cavity coupling also contributes to improved efficiency.

2.2.2 Electron Gun

The standard VA-145E electron gun was modified to produce a smaller beam that would be compatible with the reduction in drift-tunnel diameter from 0.75 inches to 0.70 inches. The change to the gun included reducing the cathode button's radius of curvature, modifying the anode shape, and reshaping the iron input pole piece. A model of the modified electron gun was built and tested in our beam analyzer. The new beam has a diameter of 0.50 inches and only 7% scalloping under normal focusing conditions. Stable beam operation was achieved over a 20% variation in magnetic focusing field. These results are an improvement over the standard VA-145E gun.

2.2.3 VKS-8345 Buncher Section Design

If the tube is to meet the required bandwidth and power-output performance, the rf buncher section must present a properly bunched beam to the extended-interaction output circuit at each frequency within the operating band. The critical variables are the frequencies and loaded Q's of the cavities and the electrical distances between them. Optimizing these parameters is greatly simplified by utilizing several computer codes that simulate klystron behavior under both small-signal and large-signal saturated conditions. After a number of iterations, a combination of cavity parameters was found that provided a satisfactory gain-bandwidth product within the VA-145E pole-piece-to-pole-piece length. In the final buncher section design, the input cavity is heavily loaded by the input loop. The second cavity is loaded

with a coupling loop connected to an external load. Cavities three and four have no coupling loops; neither do the two penultimate cavities. The first four cavities have two inductive diaphragm tuners that provide a tuning range of approximately 40 MHz. These trim tuners are used to compensate for imperfect data in the computer model and variations in the manufacturing process.

2.2.4 Other Features of the VKS-8345

Many of the components used on the VKS-8345 were taken directly from the VA-145E. The ceramic high-voltage seal, collector, and output window were adapted without change. Most of the external hardware items are identical to those used on the VA-145E. When fully dressed, the VKS-8345 is nearly indistinguishable from the VA-145E. Figure 4 is a photograph of the VKS-8345, Serial Number 001.

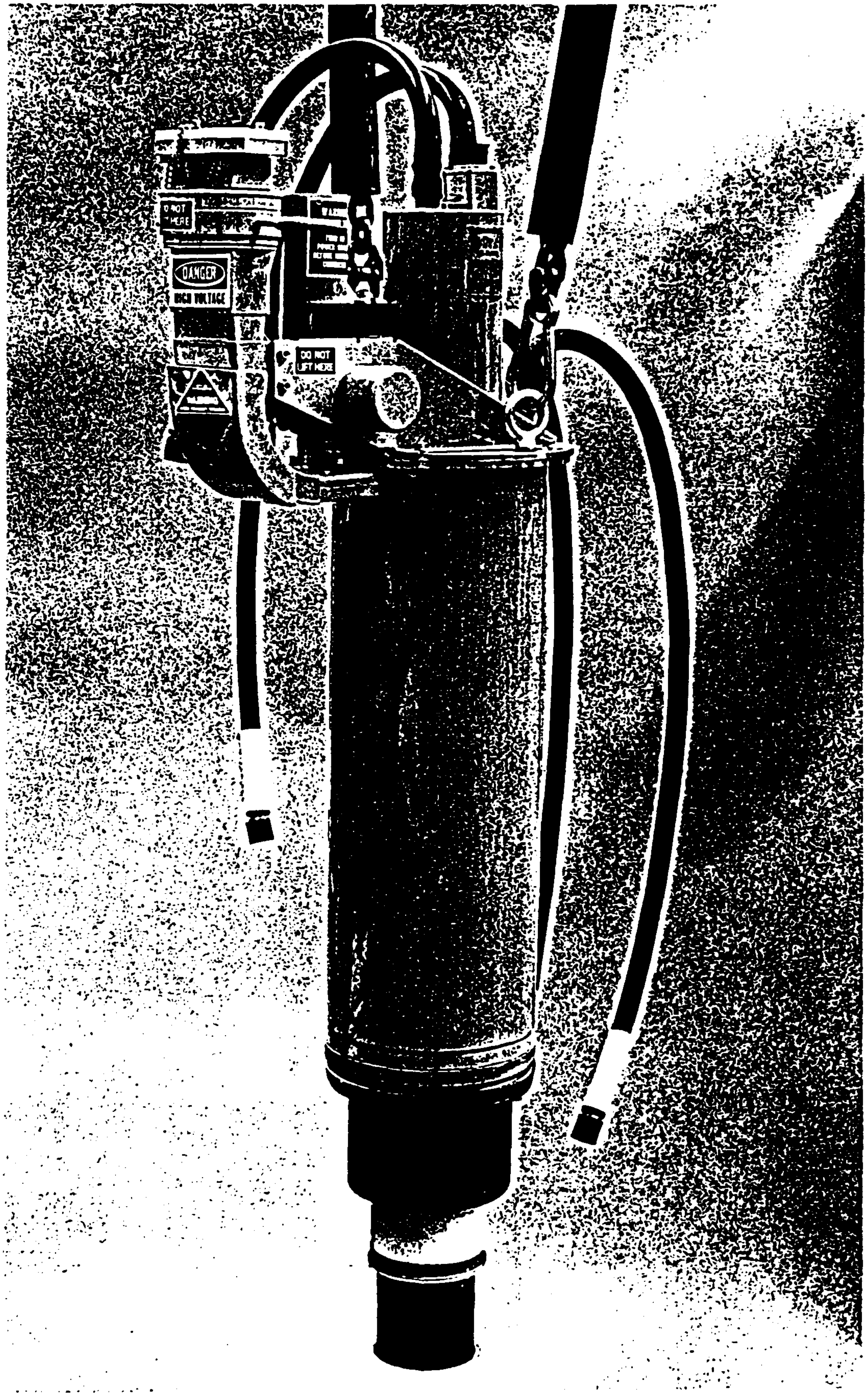

FIGURE 4.
The VKS-8345 Extended-Interaction Klystron, Serial Number 001

3.0 VKS-8345 TEST PERFORMANCE DATA

3.1 TEST RESULTS—VKS-8345, S/N 001

VKS-8345, Serial Number 001, was assembled and pumped in December 1984. Testing of this tube was completed in January 1985. At initial test, the beam perveance was found to be slightly high: 2.16 micropervs versus a maximum specification value of 2.10 micropervs. The tube's basic performance at the standard VA-145E 117-kV beam voltage was impressive. With saturated rf drive, the rf output power over the 2.9 to 3.1 GHz frequency band varied between 4.0 and 4.7 megawatts. The gain ranged from 43 to 44 dB, and the efficiency was between 40 and 46%. The output power variation across the band was 0.7 dB compared with a specification limit of 1.5 dB. Other than the maximum power output of 4.7 megawatts exceeding the maximum spec limit of 4.5 megawatts, the tube met all VA-145E basic rf performance requirements.

Although all basic rf performance expectations for S/N 001 were met, a power dip, accompanied by increased body current, occurred at 2990 MHz. A careful reexamination of the cold-test output-circuit model revealed a second-harmonic mode near the 2990-MHz frequency. This mode was determined to be an independent mode not associated with the fundamental modes of the coupled-cavity structure.

Test results for S/N 001 are shown in Figures 5, 6, and 7. Figures 5 and 6 depict rf power output under constant rf drive conditions. Figure 7 presents similar data at 115-kV beam voltage. With the exception of the second-harmonic mode dip, performance of the tube exceeded expectations, and testing was terminated.

Our efforts were next directed toward eliminating the second-harmonic mode, which was found to be in the second (upstream) of the two coupled cavities. Moving this mode out of the second-harmonic operating band proved to be a tedious process. Each dimensional change that moved the unwanted harmonic mode usually compromised the fundamental mode or pulled another higher-order mode into the band. Only after many cold-test iterations was a combination of cavity dimensions found that eliminated the unwanted harmonic mode yet preserved the desired characteristics of the fundamental mode. With this new design at hand, the tube was reassembled, processed, dressed, and tested in September 1985.

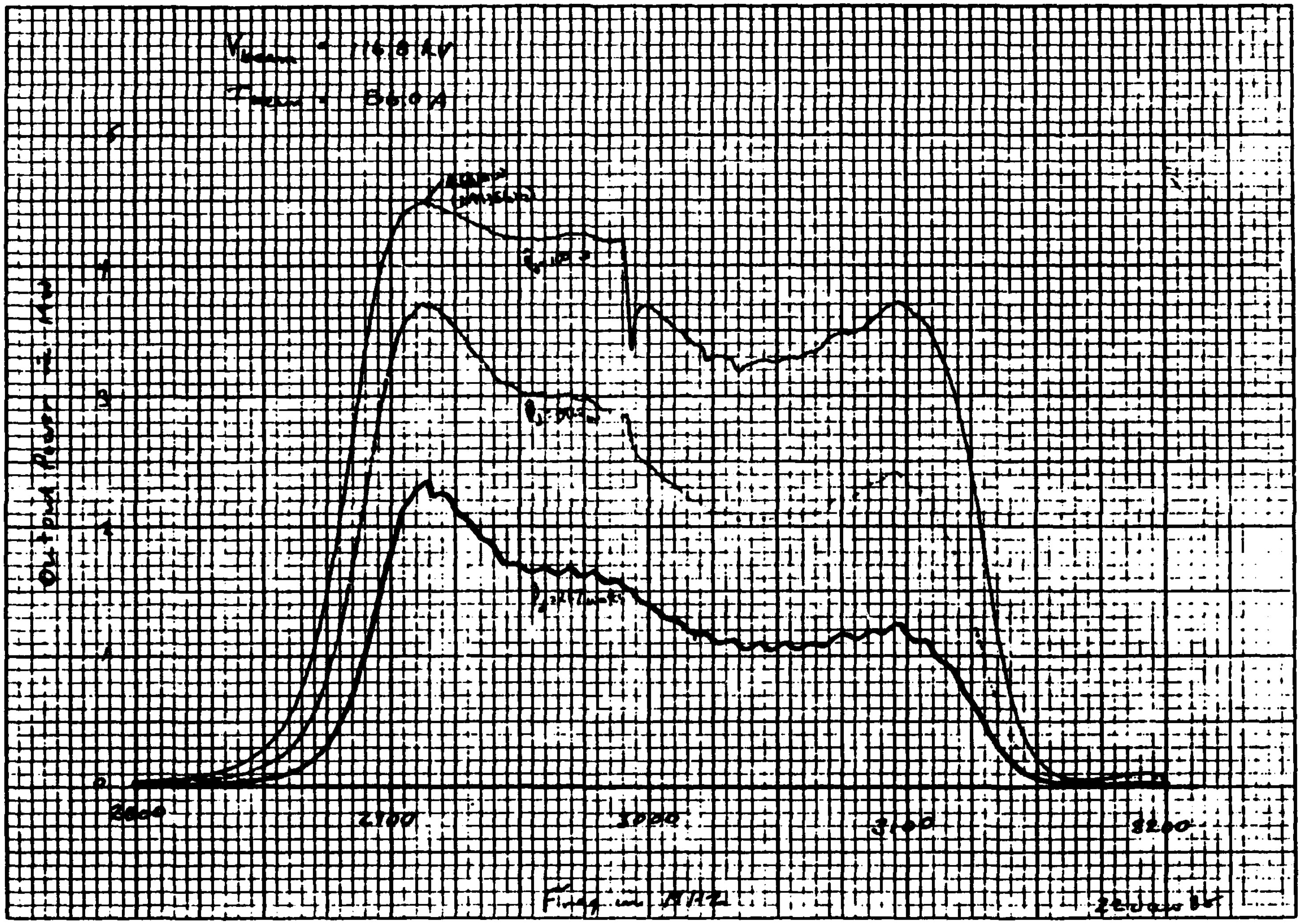

FIGURE 5
Output Power versus Frequency for Various Drive Powers
VKS-8345, S/N 001

FIGURE 6
Output Power versus Frequency for Various Drive Powers (Reduced Duty)
VKS-8345, S/N 001

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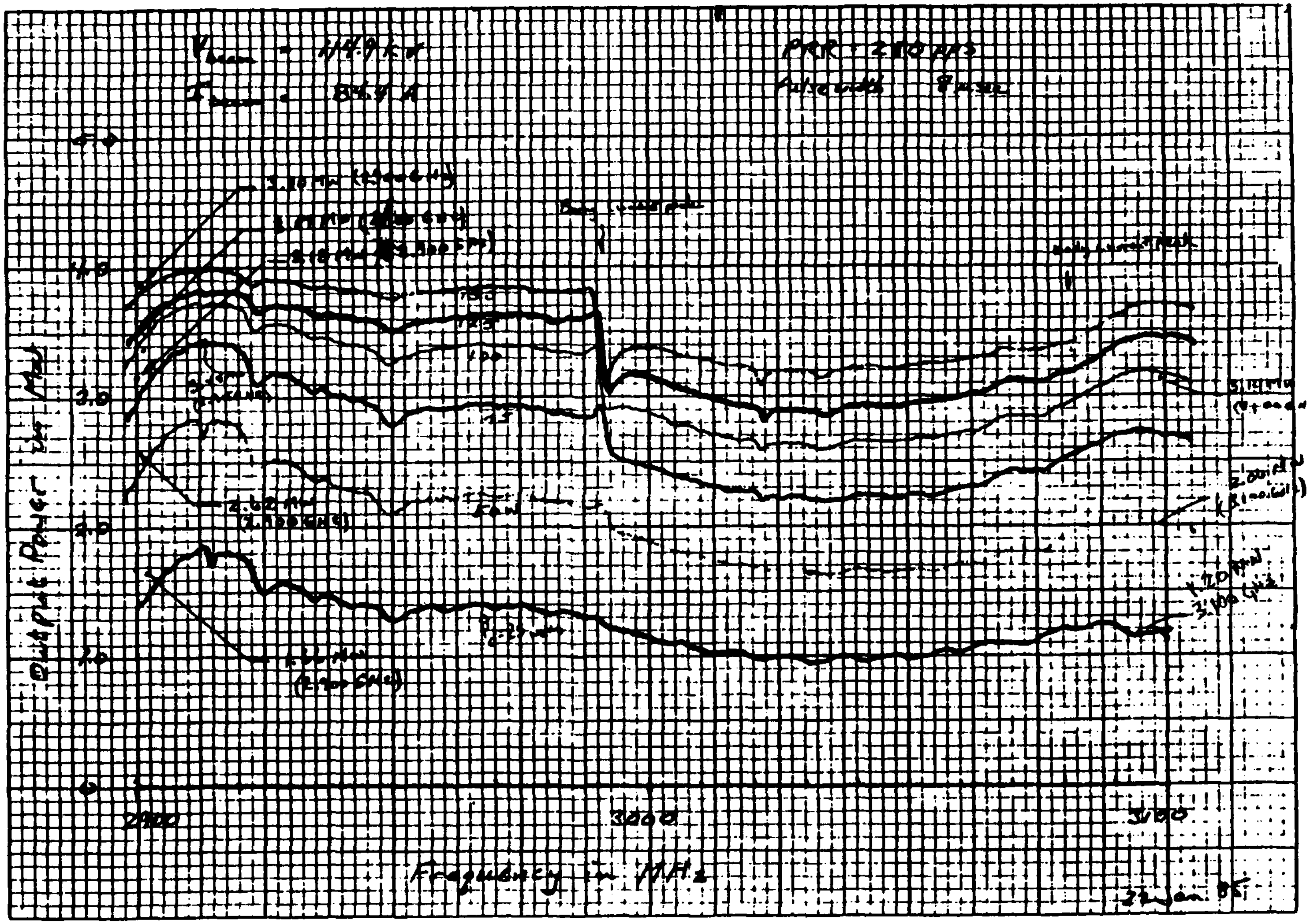

FIGURE 7
Output Power versus Frequency for Various Drive Powers (Full Duty)
VKS-8345, S/N 001

3.2 TEST RESULTS —VKS-8345, S/N 001R1

When the tube was reassembled, the electron gun cathode-anode spacing was increased slightly to reduce the gun perveance. This adjustment was only partially successful, as the perveance proved to be right at the maximum limit of 2.1 micropervs. Under these conditions, the maximum rf power output from the rebuilt tube still exceeded the maximum spec limits, but the second-harmonic mode was entirely eliminated.

Because the tube exceeded the maximum power output specification but met all other performance specifications, we decided to reduce the electron-gun perveance by pulling the gun back from the anode with an external fixture. With the gun perveance reduced to 2.05 micropervs, the tube was retested in October 1985 and met all performance specifications with the constant rf drive power of 250 watts. Typical test data at 117 kV are shown in Figure 8. The tube was then subjected to all VA-145E electrical and mechanical acceptance test procedures. The tube passed all tests; copies of the Test Performance Sheets are included in Appendix A.

After tests on S/N 001R1 were completed in Palo Alto, it was shipped to Fort Monroe, Virginia, for testing in an AN/TPS-43-E radar system. However, after installation and during checkout in the system transmitter, the tube lost its vacuum when the ceramic insulator on the VacIon® pump was accidently broken. The tube was returned to Varian for repair.

3.3 TEST RESULTS —VKS-8345, S/N 001R2

VKS-8345, Serial Number 001, was repaired, pumped, and dressed for test in February 1986. A new electron gun was used that had been modified to further reduce the gun perveance. The rebuilt tube was tested in March and again successfully met all specification requirements. Sample test data curves are shown in Figures 9 and 10, and copies of the Test Performance Sheets are provided in Appendix A. At the end of March 1986, the tube was shipped back to Fort Monroe, Virginia, for field testing as Serial Number 001R2.

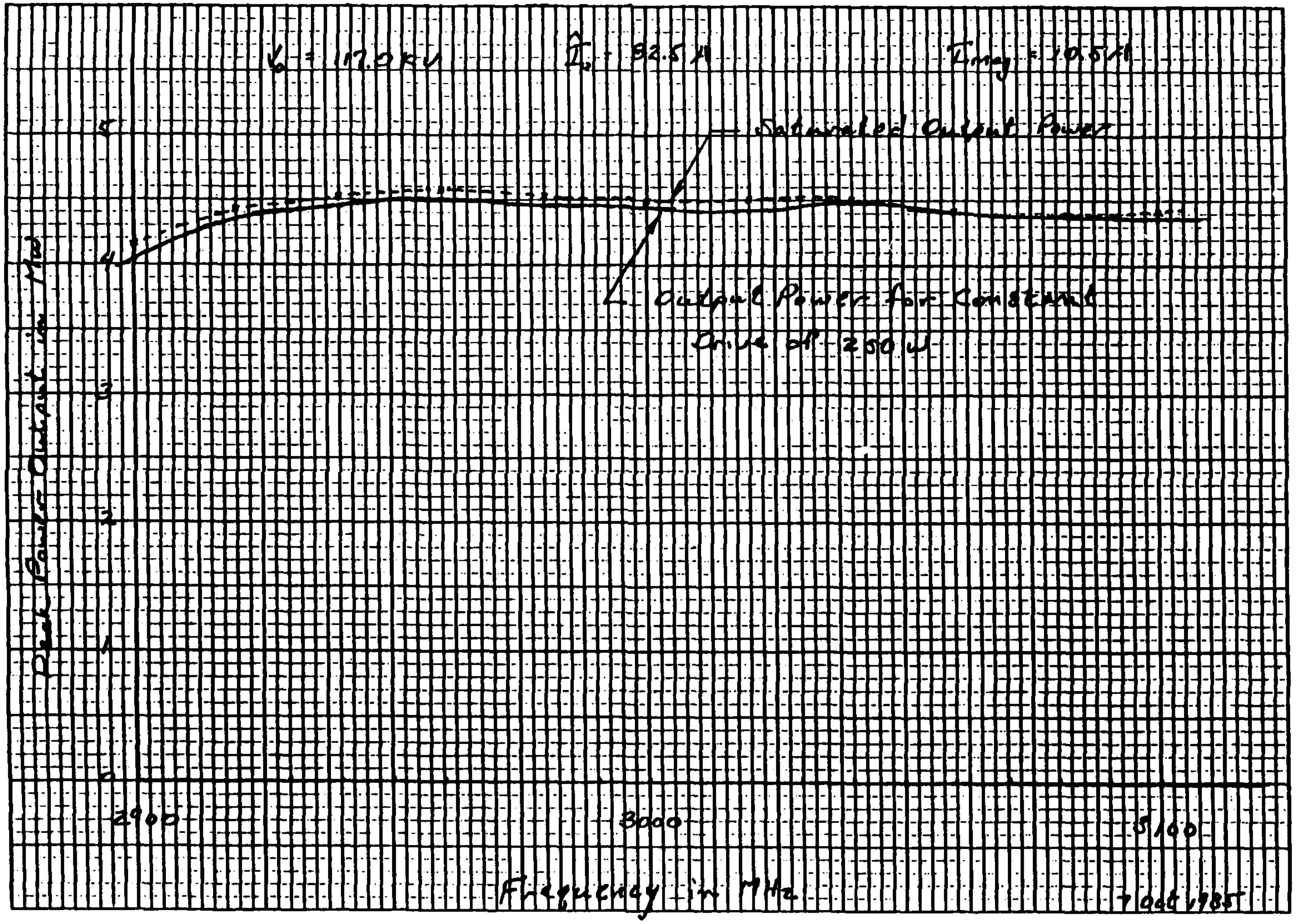

FIGURE 8
Bandwidth Characteristics of VKS-8345, S/N 001

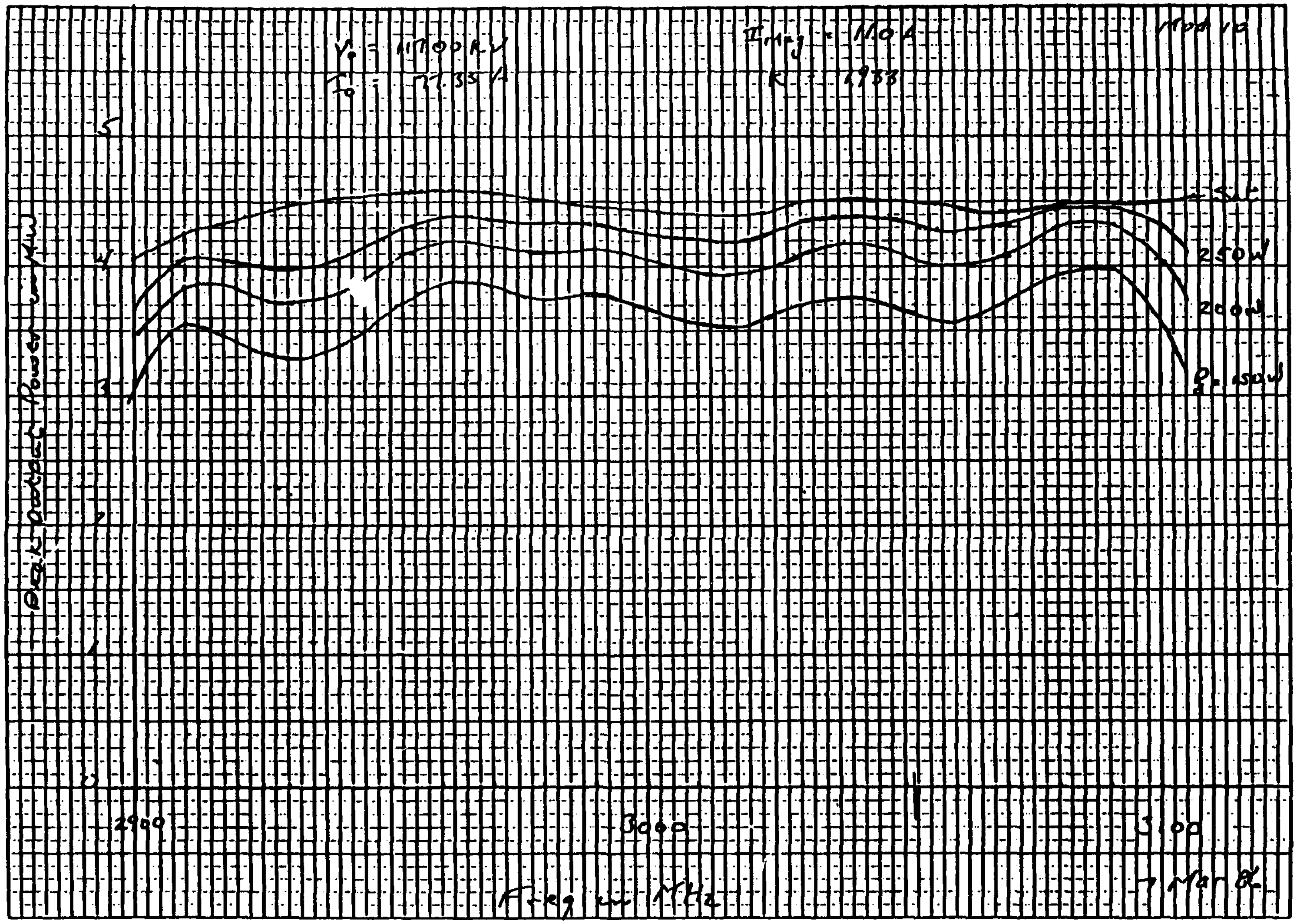

FIGURE 9
Bandpass Characteristics, VKS-8345, S/N 001R2

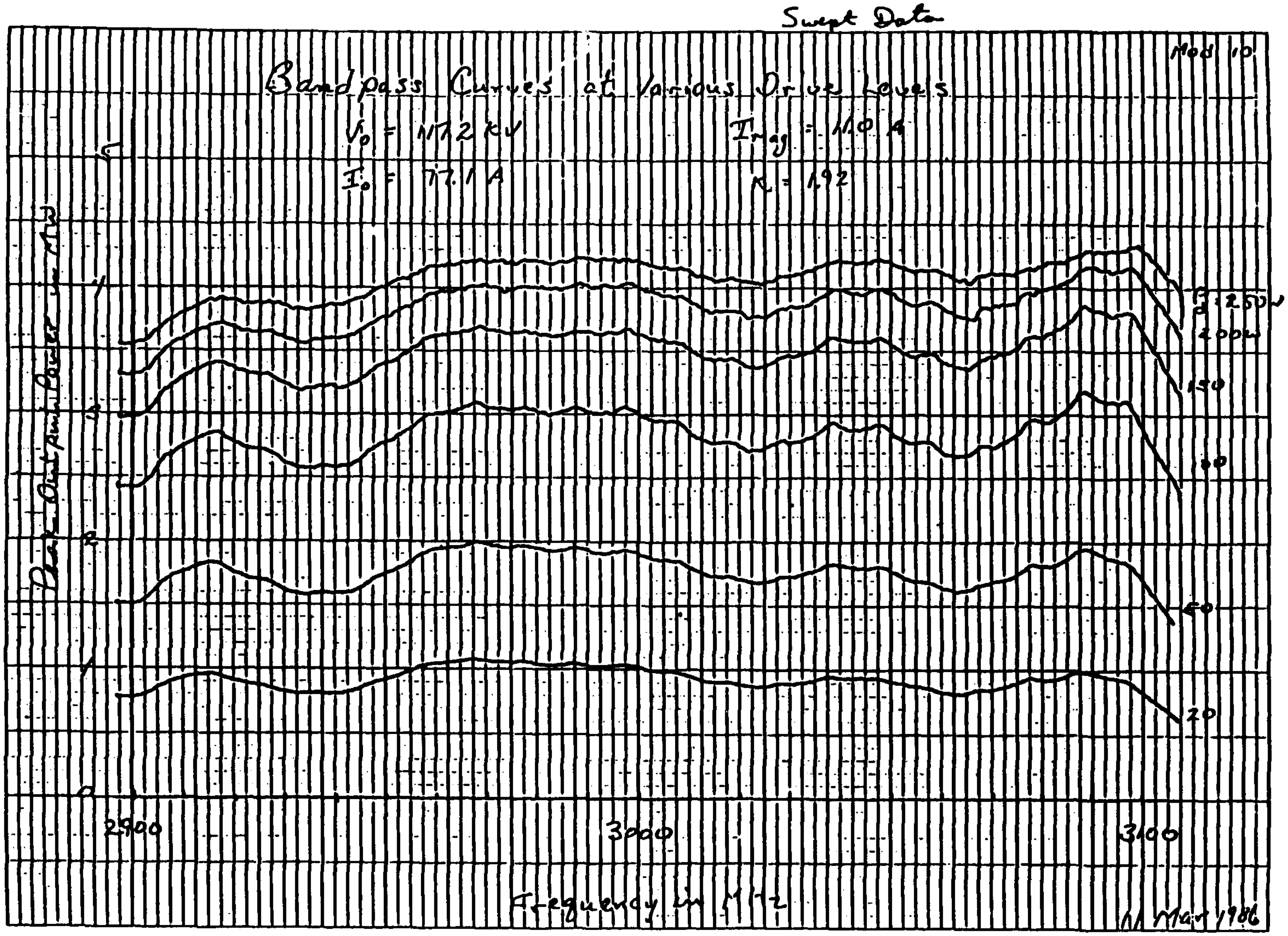

FIGURE 10
Bandpass Curves at Various Drive Levels, VKS-8345, S/N 001R2

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3.3.1 Initial VKS-8345, S/N 001R2 Site Tests

When sufficient time to test the tube could not be scheduled at Fort Monroe, arrangements were made to install and operate the tube at Luke Air Force Base in Arizona. In July 1986 the first system operation was attempted. In this initial test no meaningful data were obtained. Each time the tube was snapped on at full voltage, it arced off. Sufficient time in the equipment was not available to investigate the problem.

When S/N 001R2 was returned to Varian and installed back in the test set, it arced upon initial turn-on. The tube subsequently stabilized and performed normally. Further investigations uncovered no problems; therefore, plans were made to schedule another test in an AN/TPS-43-E system.

3.3.2 VKS-8345, S/N 001R2 Testing at Westinghouse

When a longer period of test time in an operating AN/TPS-43-E system could not be scheduled, Westinghouse Corporation agreed to test the tube in their TPS-70 test bed. The TPS-70 is an upgraded version of the AN/TPS-43-E radar system. After installation in the Westinghouse system, S/N 001R2 was initially operated into the dummy water load. Under these conditions, tube performance was normal and closely matched the Varian test performance. However, when operation was switched into the antenna system, the tube became unstable, displayed high body current, and was shut down by high reflected rf power. Stable operation was not achieved under any of the test conditions tried. Investigations revealed the possible cause of the problem (both in the TPS-70 and AN/TPS-43-E systems) was a severe waveguide mismatch just outside the high end of the frequency band. To test this hypothesis, a suitable waveguide circulator was obtained and installed in the TPS-70 waveguide system. With the circulator in place, the tube performed very well, with test results similar to those obtained when operating directly into the dummy water load. The source of most of the severe mismatch just outside the upper band edge was subsequently traced to the rotary joint. This situation, together with the fact that the extended-interaction output circuit on the VKS-8345 has a much wider impedance bandwidth than required, creates the necessary conditions for inducing self-oscillations in the extended-interaction klystron.

This an'lysis suggested two solutions to the problem: either reduce the mismatch of the rotary joint, or reduce the out-of-band impedance o' the output circuit at the high end of the frequency band. Since it was not feasible to modify/replace the rotary joints in all existing AN/TPS-43-E radar systems, the logical choice was to modify the impedance bandwidth characteristic of the extended-interaction output circuit.

3.4 VKS-8345, S/N 002

Rather than rebuild S/N 001R2 again, a second tube nearly identical to S/N 001 was assembled. In the new tube, the output circuit's bandpass characteristic was shifted lower in frequency to reduce the out-of-band impedance above the high end of the frequency band. Serial Number 002 was completed and tested in October 1987. The tube performed very well when operated into a standard water load and met all specifications. Sample test data are shown in Figure 11. When a borrowed AN/TPS-43-E rotary joint was installed in the test set in a fixed orientation, the tube continued to perform well, yielding essentially the same test data as shown in Figure 12. To confirm the improved performance of S/N 002, S/N 001R2 was installed in a test set and operated into the rotary joint. Above a beam voltage of 72 kV, S/N 001R2 exhibited oscillations at a frequency of 3340 MHz. A VSWR-versus-frequency plot for the rotary joint showed a good in-band match, but a 12:1 mismatc was present at approximately 3340 MHz. The higher impedance level of the output circuit in S/N 001R1 was apparently sufficient to create an unstable operating condition in the face of a severe mismatch.

As a final check, S/N 002 was returned to the test socket and operated at full duty into the rotary joint. Again the tube performed normally with no evidence of oscillations or instabilities (see Figure 12). In all of the above tests, the rotary joint was held in a fixed position.

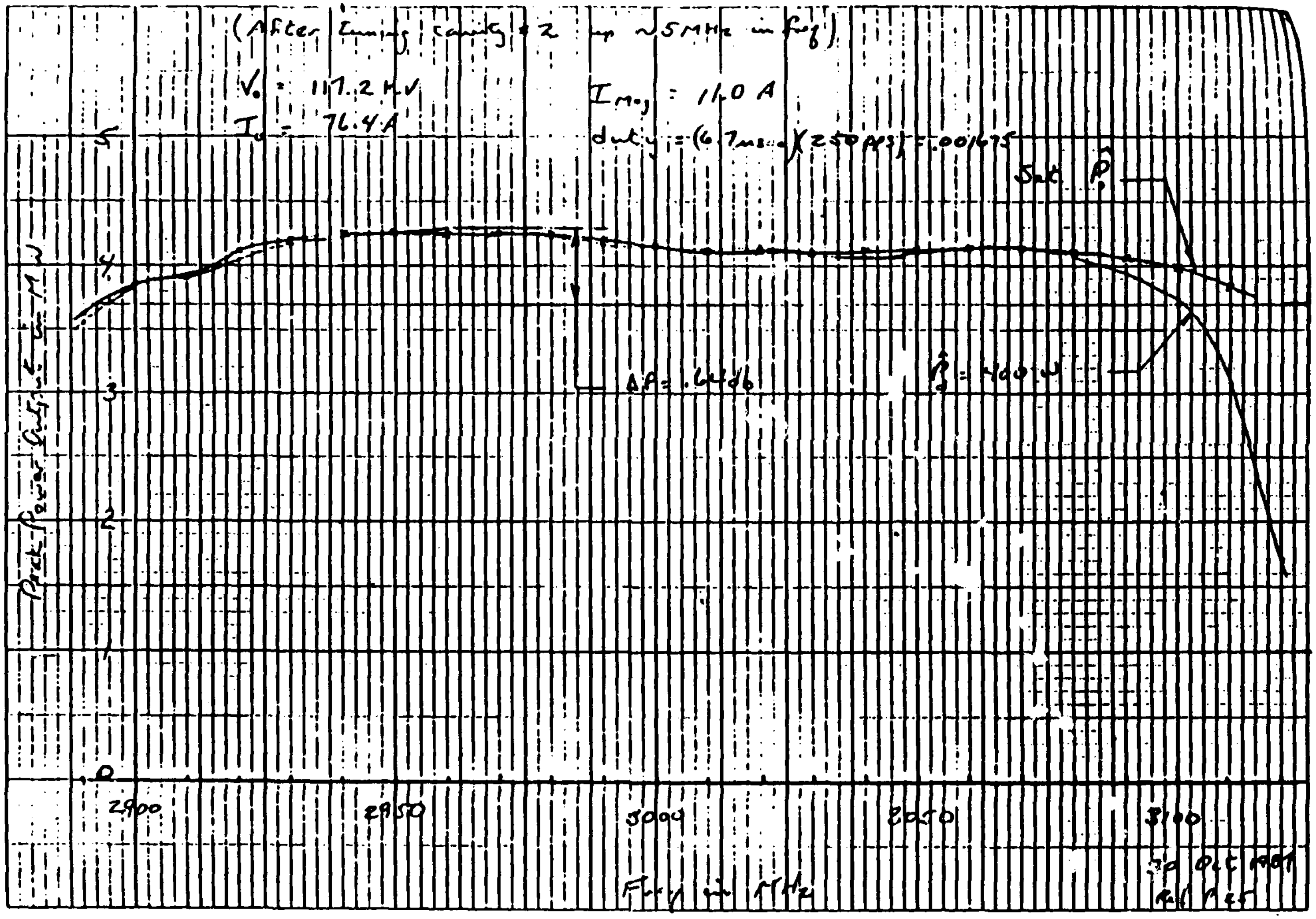

FIGURE 11
Power Output versus Frequency for VKS-8345, S/N 002

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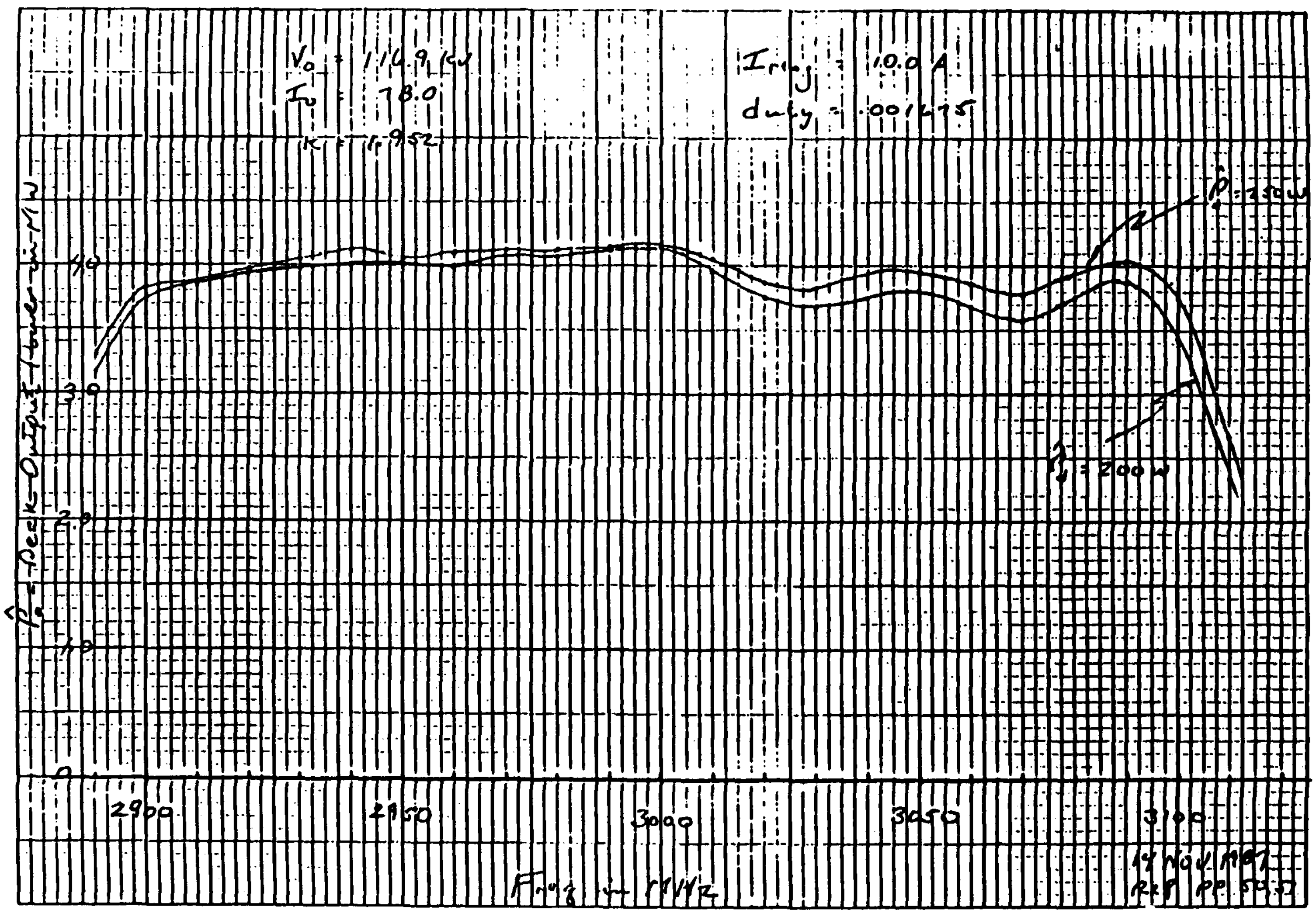

FIGURE 12
Output Power versus Frequency for VKS-8345, S/N 002, Operating Into a Rotary Joint

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3.4.1 VKS-8345, S/N 002 Testing at Westinghouse

S/N 002 was finally installed and tested in a TPS-70 transmitter at Westinghouse in April 1988. The tube operated well in the system at certain orientations of the antenna, but at other orientations oscillations occurred. Both self-oscillations and drive-induced oscillations were observed, and at sufficiently high power levels the tube would trip off. At those antenna orientations producing satisfactory operation, the measured performance was comparable to Varian test data. Although VKS-8345 S/N 002 was not usable in the TPS-43/70 systems, its performance was an improvement over that of S/N 001R2.

3.5 DESIGN AND TEST OF VKS-8345, S/N 003

With the expectation that the design of the extended-interaction output circuit could be modified to operate benignly in the presence of the severe mismatch near the upper band edge, a third tube was built and tested. As described earlier in Section 2.0, in an overlapping-mode extended-interaction output circuit, both the π mode and the 2π mode are located in or near the desired bandpass of the circuit. In the original design, the 2π mode, which is the upper mode, was located at about 3227 MHz. In S/N 003, the 2π-mode point was reduced to 3168 MHz. Here again the goal was to reduce the out-of-band impedance at the troublesome 3340 MHz frequency range.

S/N 003 was assembled and tested in June 1990. As with the previous tubes, this tube performed well and met all specifications when operating into the standard water load. Sample test data are shown in Figure 13. At the completion of tests, the rotary joint was installed in the test set, but with provisions made to allow rotation of the joint with the water load attached. Testing into this waveguide setup produced results similar to those demonstrated by S/N 002 in the TPS-70 transmitter at Westinghouse. S/N 003 operated satisfactorily at certain rotary-joint orientations, but exhibited oscillations at other orientations.

A careful VSWR mapping of the rotary joint at various orientations showed the mismatch in the 3340 MHz region varied from a low of 12:1 to a high of 300:1 in the worst case. Figures 14, 15, and 16 provide examples of the test data. We then concluded that further adjustments of the extended-interaction output bandpass characteristics would probably not overcome the severe mismatch problem in the rotary joint. Since other tube-related solutions to this problem were deemed to be outside of the scope of this contract, the program was concluded.

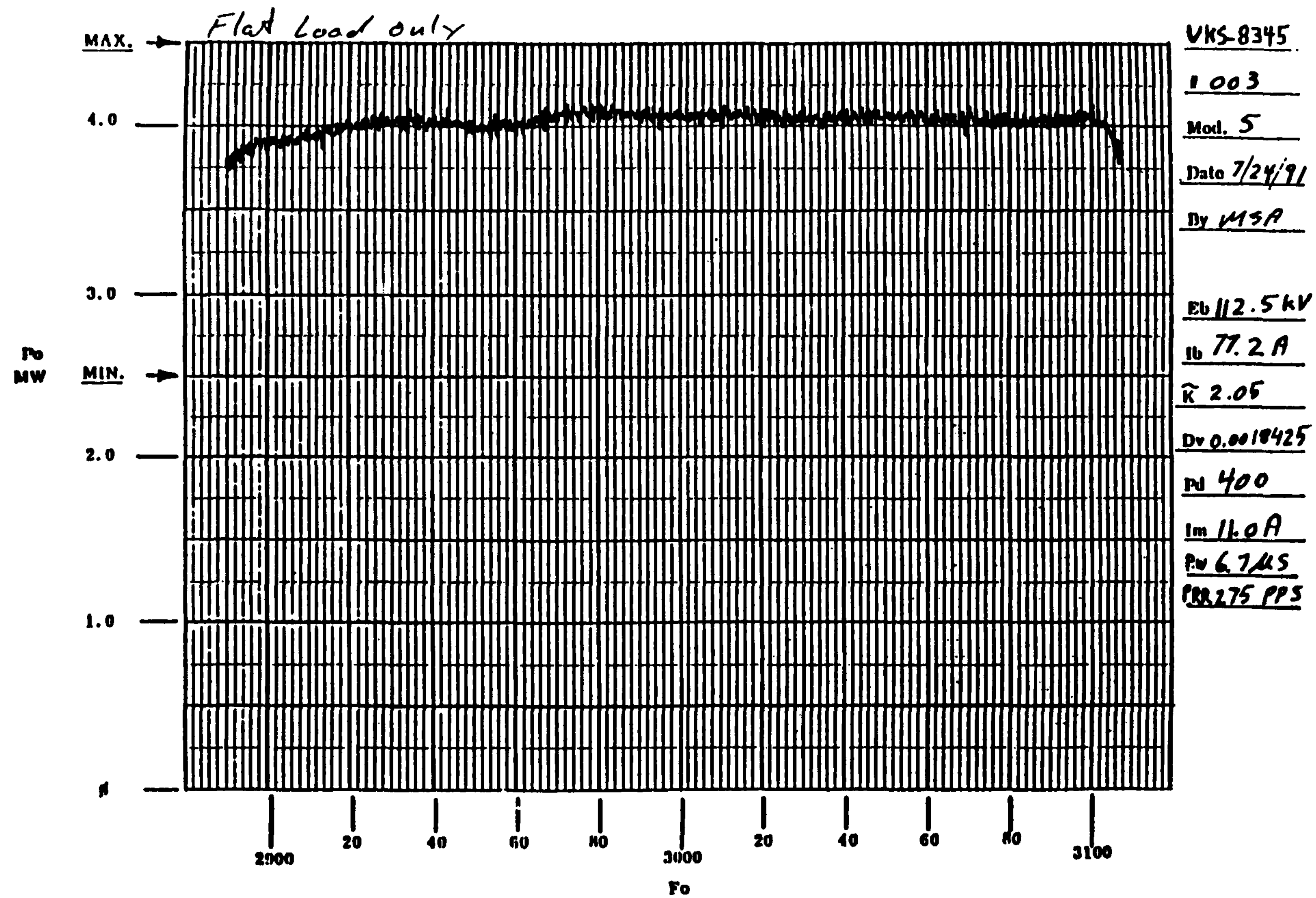

FIGURE 13
Power versus Frequency for VKS-8345, S/N 003, Operating Into the Standard Water Load

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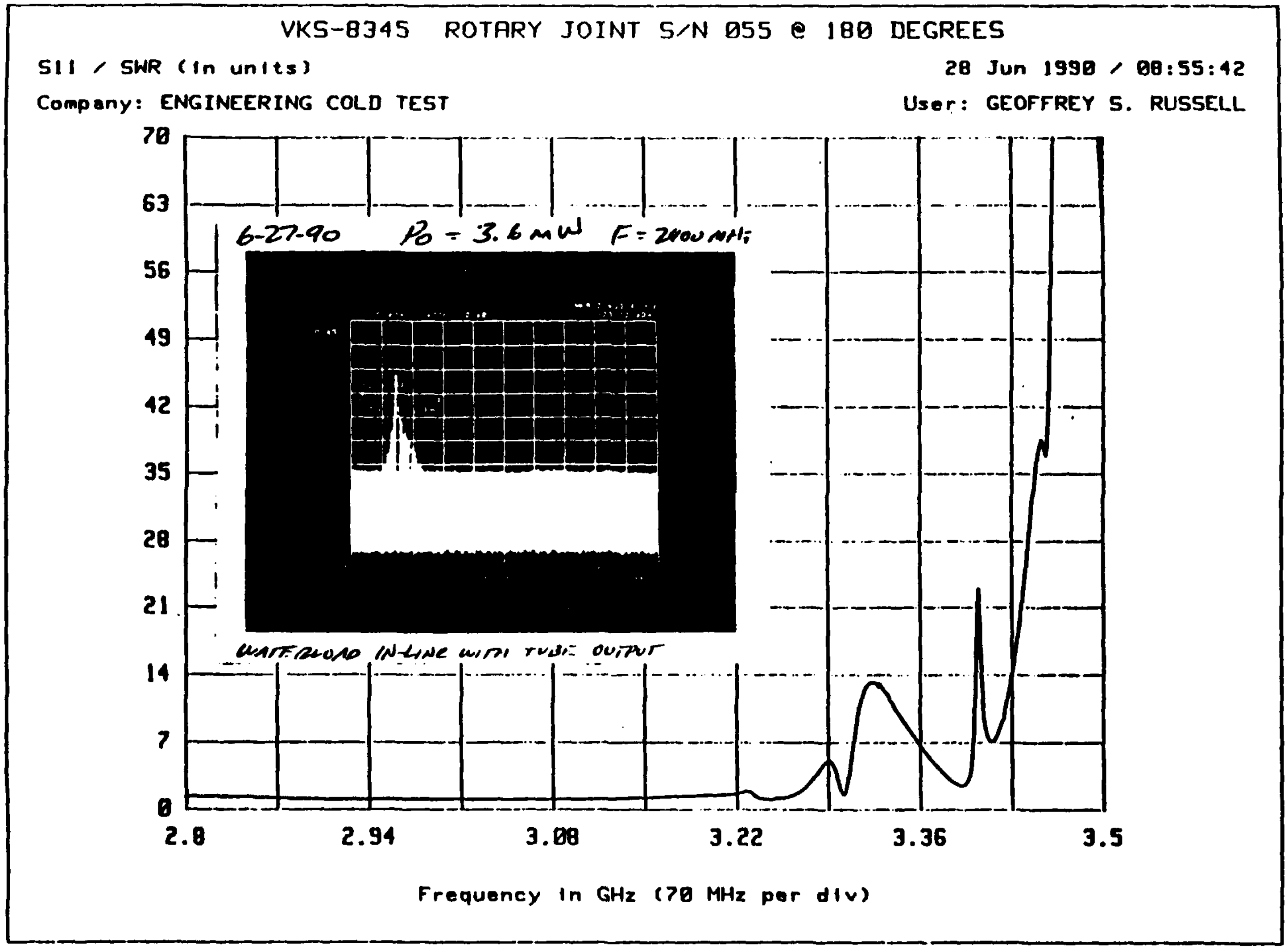

FIGURE 14
VKS-8345, S/N 003 Mismatch; Rotary Joint at 180° Orientation

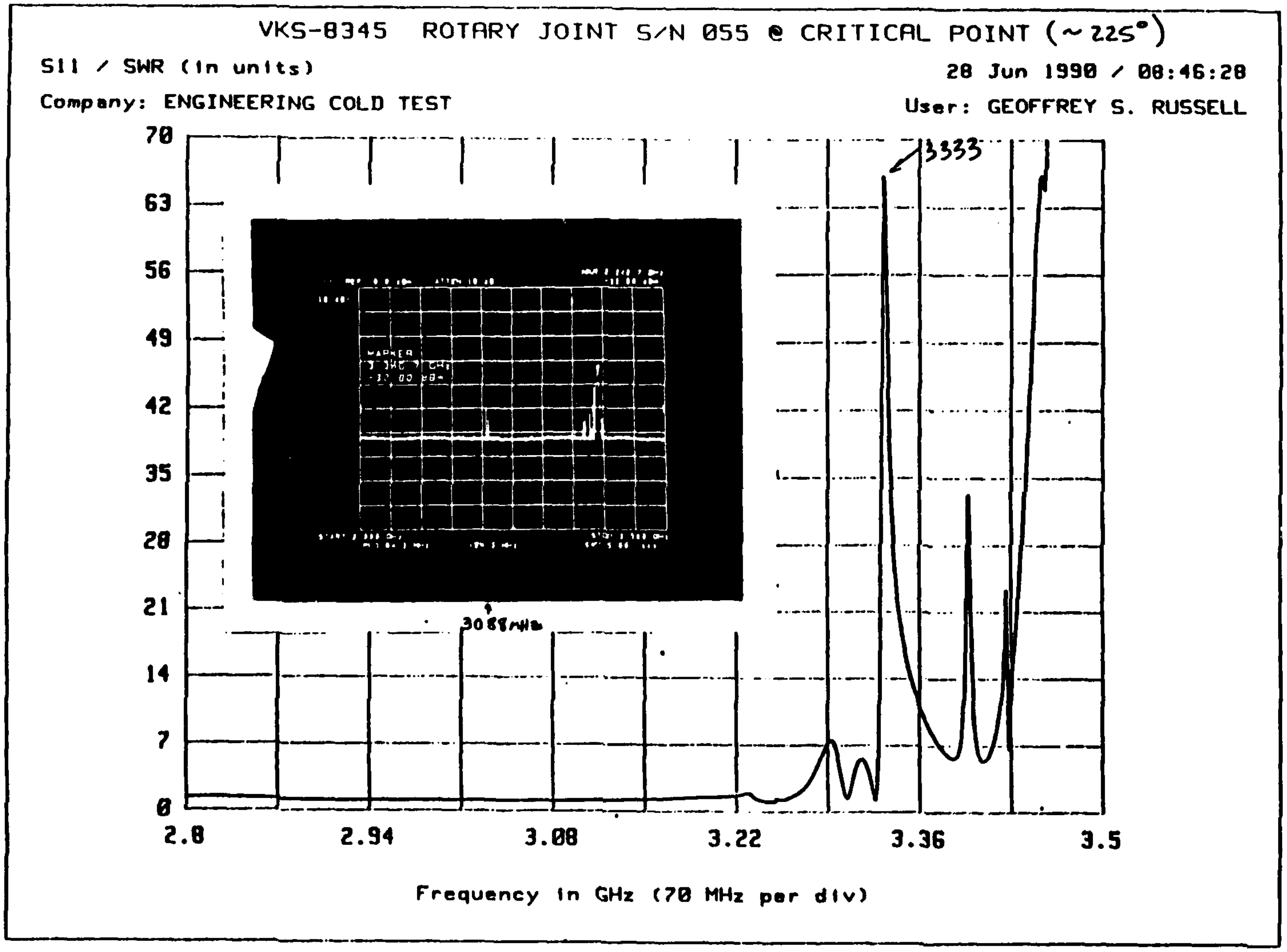

FIGURE 15
VKS-8345, S/N 003 Mismatch; Rotary Joint at ~225° Orientation

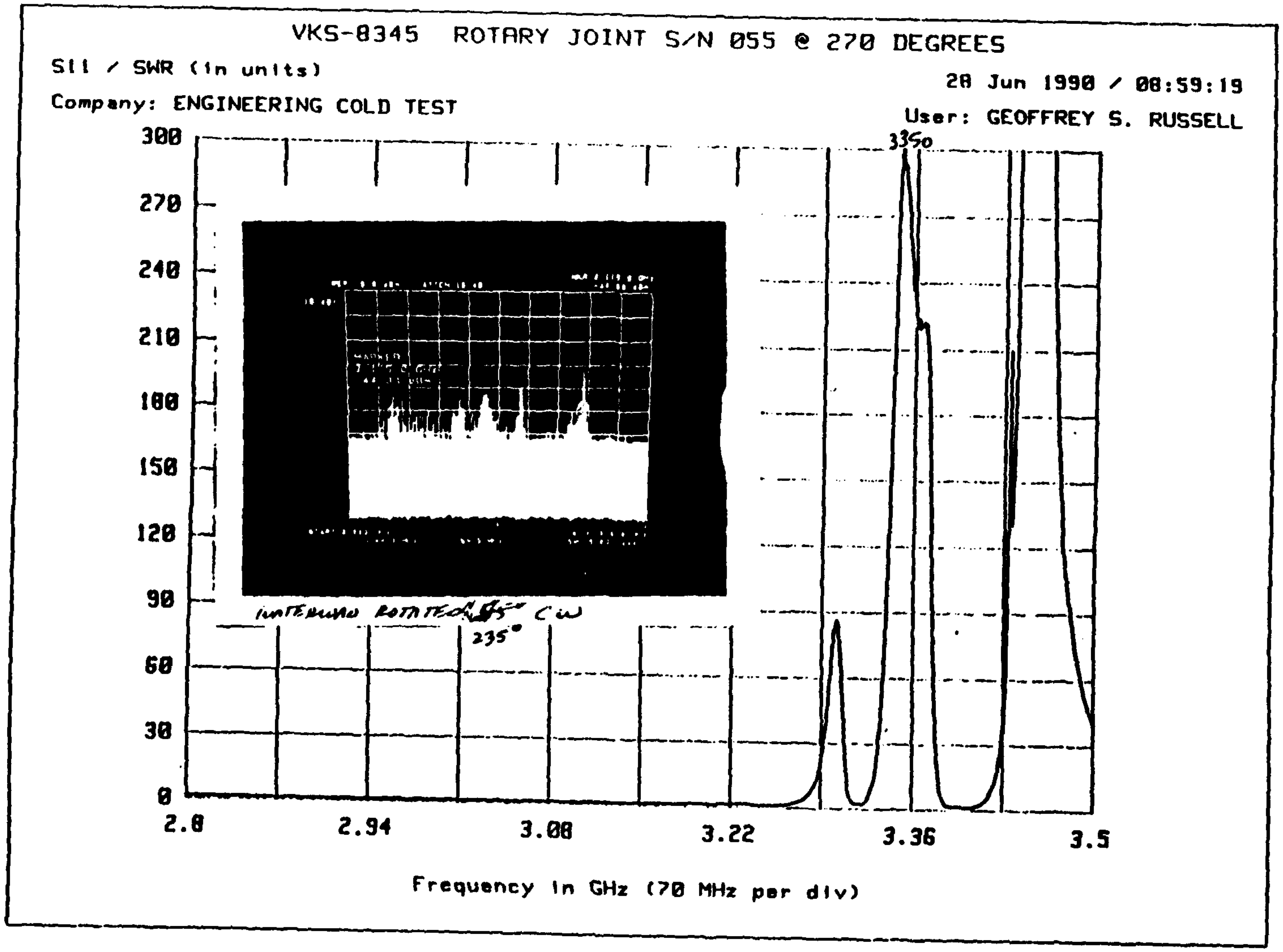

FIGURE 16
VKS-8345, S/N 003 Mismatch; Rotary Joint at 270° Orientation

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4.0 CONCLUSIONS AND RECOMMENDATIONS

The results from the three VKS-8345 extended-interaction klystrons built and tested under this program demonstrated conclusively that the extended-interaction output circuit can provide wide bandwidths with exceptional flatness and high efficiency in a high-power klystron. However, the goal of achieving a drop-in replacement for the VA-145E in the existing AN/TPS-43-E transmitter was not achieved because of tube instabilities induced by the severe near-band mismatch conditions existing in the rotary joint. Two attempts to overcome the problem by modifying the extended-interaction output circuit did not yield satisfactory results. The problem may still be overcome by clever output-circuit design, but we need to explore new ideas.

Other tube-related solutions to this out-of-band instability problem are possible. One such idea would be to incorporate waveguide filter elements in the output waveguide of the tube to control the amplitude and phase angle of the mismatch. While such a scheme is considered possible, the task was outside the scope of the present program.

Finally, the wideband extended-interaction klystron design that evolved from this program is certainly a superior candidate for use in radar systems that either incorporate a waveguide circulator or have a rotary joint with a better near-band VSWR response.

5.0 REFERENCES

1. "Proposal for a Product Improvement Program for the TPS-43 Final Amplifier Tube," Varian Associates Technical Proposal VATP 82-60061, April 1982.

2. "Wideband Extended Interaction Klystron," Varian Final Technical Report, Contract No. F30602-80-C-0089 for Rome Air Development Center, November 1984, including Addendum of September 1987; Section II, Paragraph D—Output Resonator.

3. "Extended-Interaction Resonator Development," Final Technical Report, Contract No. F30602-78-C-0029.

APPENDIX A

Test Performance Sheets
VKS-8345, S/N 001

Test Performance Sheets
VKS-8345, S/N 001R1

TEST PERFORMANCE SHEET
KLYSTRON AMPLIFIER
TUBE TYPE NO. VKS-8345
SERIAL NO. 001
Data Sheet 1 of 2

varian

QA No. 107-60
EO 10-111751
October 7, 1982
Rev. Issue

Purchase Order/Contract F30602-83-C-0161

QUALITY CONFORMANCE INSPECTION

TEST	CONDITIONS						TEST RESULTS
Vacuum Check:	No Operating Voltages, Vacion® Pump indication to be less than 10^{-7} Torr 15 minutes after activation at end of a 72 hour minimum Holding Period.						
Hydrostatic Pressure, Body and Collector	P = 150 psig minimum water pressure, applied 5 minutes. No leakage or damage.						NO LEAKAGE
Output Window Pressurization:	Pressurize with air to 30 psig. Pressure after 15 minutes to be not less than 28 psig.						30.0 PSI
X-Radiation:	Tube operated in Power Output conditions at f = 3.1 GHz. Maximum radiation to be less than 2.5 mR/hr at 3 feet from tube above the base plane of the solenoid.						1.5 mR/hr
		Value		Min	Max	Units	
Pressure Drop, Collector	With a water flow of 6 GPM through the collector, the pressure drop shall not exceed 45 psi.	psi	20.5	---	45	psi	
Pressure Drop, Body	With a water flow of 1.5 GPM	psi	8.0	---	15	psi	
Heater Current	Ef = 7.5 V	If	32.0	30	36	Adc	

CAUTION:
(1) All voltages are with respect to cathode. For safety, external package must be grounded.
(2) If dc heater voltage is used on this tube, the heater must be negative with respect to the heater-cathode.

OUTLINE DRAWING NO.	PRODUCT SAFETY REVIEW
R-191295	026191

Tested By [signature] Varian QA varian QA 2 Customer Rep. ______

Date 07 OCT 85 10/10/85 ______

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TEST PERFORMANCE SHEET
KLYSTRON AMPLIFIER
TUBE TYPE NO. VKS-8345
SERIAL NO. 001
Data Sheet 2 of 2

QA No. 107-60
EO 10-111751
October 7, 1982
Rev. Issue

QUALITY CONFORMANCE INSPECTION — 1

SERIAL NUMBER 001

TEST	CONDITIONS		Value	Min	Max	Units
Power Output	Ef = 7.5 V tk = 15 min					
	VSWR 1.1, Waveguide Pressure 23 psig min					
	epy = 117 kV tp(epy) 7.2 μs min					
	PRF 250, rf Du 0.001675					
	Electromagnetic Current	Imag	10.5	9.5	11.0	Adc
	Drive Power	Pd	See Table	---	.8	kW
	Operating Bandwidth	F	See Table	2.9	3.1	GHz
	Peak Power Output	Po	See Table	2.5	4.5	mW
	Beam Current	Ib	82.5	76	84	Adc
	Body Current	Iby	19.5	---	30	mAdc
	Oscillations	---	NONE	---	-60	dB
Flange Arcing	po	No sign of arcing NONE NOTED				
Dimensions	Per Outline Drawing ________					

Power Output Test Table or Curves

Frequency MHz	pd w	po Mw 117 kV	* po Mw	Frequency MHz	pd w	po Mw 117 kV	* po Mw
2900	250	4.03	4.17	3020	250	4.41	4.50
2920	250	4.36	4.43	3040	250	4.48	4.51
2940	250	4.46	4.53	3060	250	4.40	4.40
2960	250	4.50	4.59	3080	250	4.36	4.36
2980	250	4.45	4.52	3100	250	4.36	4.41
3000	250	4.43	4.49				

*Adjust drive, up to 2 kW level, for max po at each frequency across band and record po.

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TEST PERFORMANCE SHEET
KLYSTRON AMPLIFIER
TUBE TYPE NO. VKS-8345
SERIAL NO. 001 R1

Data Sheet 1 of 2

QA No. 107-60
EO 10-111751
October 7, 1985
Rev. Issue

Purchase Order/Contract F030602-83-C-0161

QUALITY CONFORMANCE INSPECTION

TEST	CONDITIONS			TEST RESULTS		
Vacuum Check:	No Operating Voltages, Vaclon® Pump indication to be less than 10^{-7} Torr 15 minutes after activation at end of a 72 hour minimum Holding Period.			10^{-9}		
Hydrostatic Pressure, Body and Collector	P = 150 psig minimum water pressure, applied 5 minutes. No leakage or damage.			NO LEAKAGE		
Output Window Pressurization:	Pressurize with air to 30 psig. Pressure after 15 minutes to be not less than 28 psig.			30.0 PSI		
X-Radiation:	Tube operated in Power Output conditions at f = 3.1 GHz. Maximum radiation to be less than 2.5 mR/hr at 3 feet from tube above the base plane of the solenoid.			0.4 mR/hr		
		Value		Min	Max	Units
Pressure Drop, Collector	With a water flow of 6 GPM through the collector, the pressure drop shall not exceed 45 psi.	psi	23.0	---	45	psi
Pressure Drop, Body	With a water flow of 1.5 GPM	psi	7.5	---	15	psi
Heater Current	Ef = 7.5 V	If	31.6	30	36	Adc

CAUTION:
(1) All voltages are with respect to cathode. For safety, external package must be grounded.
(2) If dc heater voltage is used on this tube, the heater must be negative with respect to the heater-cathode.

OUTLINE DRAWING NO.	PRODUCT SAFETY REVIEW
R-191295	026191

Tested By [signature] Varian QA varian QA12 Customer Rep. ____________

Date 10 MAR 86

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TEST PERFORMANCE SHEET
KLYSTRON AMPLIFIER
TUBE TYPE NO. VKS-8345
SERIAL NO. 001R1
Data Sheet 2 of 2

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QA No. 107-60
EO 10-111751
October 7, 1982
Rev. Issue

QUALITY CONFORMANCE INSPECTION — 1

SERIAL NUMBER 001R1

TEST	CONDITIONS		Value	Min	Max	Units
Power Output	Ef = 7.5 V tk = 15 min					
	VSWR 1.1, Waveguide Pressure 23 psig min					
	epy = 117 kV tp(epy) 7.2 μs min					
	PRF 250, rf Du 0.001675					
	Electromagnetic Current	Imag	11.0	9.5	11.0	Adc
	Drive Power	Pd	See Table	---	.8	kW
	Operating Bandwidth	F	See Table	2.9	3.1	GHz
	Peak Power Output	Po	See Table	2.5	4.5	mW
	Beam Current	Ib	78.2	76	84	Adc
	Body Current	Iby	10.5	---	30	mAdc
	Oscillations	---	NONE	---	-60	dB
Flange Arcing	po	No sign of arcing	NONE NOTED			
Dimensions	Per Outline Drawing	JOHN S. QA				

Power Output Test Table or Curves

Frequency MHz	pd w	po Mw 117 kV	* po Mw	Frequency MHz	pd w	po Mw 117 kV	* po Mw
2900	250	3.52	3.99	3020	250	4.10	4.32
2920	250	3.84	4.28	3040	250	4.23	4.40
2940	250	3.95	4.43	3060	250	4.06	4.29
2960	250	4.28	4.48	3080	250	4.23	4.30
2980	250	4.24	4.45	3100	250	4.12	4.43
3000	250	4.20	4.33				

*Adjust drive, up to 2 kW level, for max po at each frequency across band and record po.

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